

Self-Healing Properties of Silicone Rubber Against Relative Humidity and Nanofiller

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Abstract

A well-prepared abstract enables the reader to identify the basic content of a document quickly and accurately, to determine its relevance to their interests, and thus to decide whether to read the document in its entirety. The Abstract should be informative and completely self-explanatory, provide a clear statement of the problem, the proposed approach or solution, and point out major findings and conclusions. The Abstract should be 100 to 150 words in length. The abstract should be written in the past tense. Standard nomenclature should be used and abbreviations should be avoided. No literature should be cited. The keyword list provides the opportunity to add keywords, used by the indexing and abstracting services, in addition to those already present in the title. Judicious use of keywords may increase the ease with which interested parties can locate our article.

Keywords: self-healing properties, silicone rubber, relative humidity, nanofiller, leaf-like specimen

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1. Introduction

Electrical tree is a pre-breakdown phenomenon in polymeric insulation material which occurs at the region of high divergent field such as voids, grazes, defects, protrusions, impurities and cracks [1]. It is a damaging process which cause by partial discharge and progresses through the stressed dielectric insulation. Electrical treeing is involving electrical, chemical and mechanical processes. Electrical treeing is a breakdown mechanism that usually happened in polymeric materials and it is a main factor of electrical faults in high voltage applications.

In self-healing systems, there are transitions from hard-to-soft matter in ballistic impact and solvent bonding and conversely, soft-to-hard matter transitions in high rate yielding materials and shear-thickening fluids. These transitions are examined in terms of a new theory of the glass transition and yielding, the twinkling fractal theory of the hard-to-soft matter transition. Success in the design of self-healing materials has important consequences for material safety, product performance and enhanced fatigue lifetime [2].

Self-healing materials have the structurally incorporated ability to repair damage. It is capable of filling voids in or at least partially repairing damage to a dielectric material in which internal partial discharge occurs. According to the healing effect developed, self-healing polymers can be classified into two categories which are intrinsic and extrinsic self-healing. Extrinsic self-healing is able to heal cracks by the polymers with any additional healing agent. Upon being damaged, healing agent would be released and then polymerized to reconnect the cracks. In case intrinsic self-healing, it is able to heal cracks by the polymers themselves without any additional healing agent [3]. The properties of the self-healing that occurred in dielectric material can be investigated by measuring the decrease of tree length, tree area and weight of the specimen. For an instance, the dielectric material which has a good self-healing property is silicone rubber (SiR).

There are many experiments have been conducted by other researchers to obtain electrical treeing under environmental stress. Humidity environment will give a great effect on not only the electrical and physiochemical properties but also the mechanism of electrical trees. Besides that, the experiment of the relationship between electrical tree propagation

characteristics and the humidity environment has been examined. The proportion of the treeing which is a new parameter is introduced to clarify the propagation characteristics of trees [4]. The formation of electrical tree within insulating layer of cables under moisturized soil has been investigated [5]. The formation of water trees in insulation is a major cause of insulations failure [6].

Many researchers have been investigating on this research field [3,7,8]. However, effect of nanofiller and humidity on self-healing properties of SiR is not clearly understood. The objective of this research work is to investigate the effect of humidity and nanofiller amount against self-healing performance of SiR.

2. Research Method

2.1. Sample Preparation

The most essential part in this investigation is preparation of the needles tip. The tip of the needles has to follow the specifications in order to obtain a good result in this experiment. Each of the needles need to be checked their tip radius and placed in a distance of 2mm from the ground electrode. The needle tip have been sharpen using electrolytic polishing using sodium hydroxide (NaOH) solution with a DC supply (30V, 3A). The sample types in this work are neat SiR, neat SiR with 90% of humidity, SiR added with SiO₂ by percentage of 0, 2, 4, and 6 wt%, respectively.

The schematic diagram of leaf-like specimen is shown in Figure 1. Samples for this experiment will be produced in form of leaf-like specimen as shown in Figure 1. The length of the distance between the needle tip and grounding electrode is set to 2mm. After the nanocomposites were prepared, this nanocomposites polymer was pour above the specimens and the slide glass was used to cover its top surface. Then the specimens were heated in the oven for 45 minutes at 100°C. For the neat samples, the specimens will be exposed at room temperature for 24 hours. While for performing humidity effect, the neat silicone rubber will be leaved in the humidity chamber with 90% humidity for two days after the specimens were heated in the oven for 45 minutes.

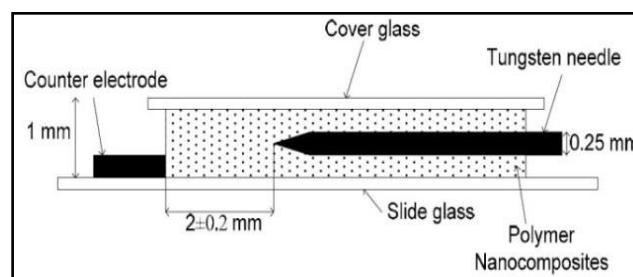


Figure 1. Side view of schematic diagram of leaf-like specimen [3]

2.2. Experiment

Figure 2 Shows the experimental setup for electrical tree monitoring investigation and self-healing performance of SiR. The tree inception time and tree propagation time for electrical treeing of neat silicone rubber and silicone rubber filled with nanofillers and neat silicone rubber with 90% humidity are observed and recorded using a microscope-online monitoring system. The propagation of tree is obtained by applying the DC voltage to the specimens. The voltage are kept increase until 10kV with the increasing rate of 1kV/second and wait until the tree start to initiate and turn off the voltage when the electrical treeing length reach at 70%-80% of 2mm gap length. The tree inception time, tree propagation time and tree length is recorded in the computer by using Cellsens software.

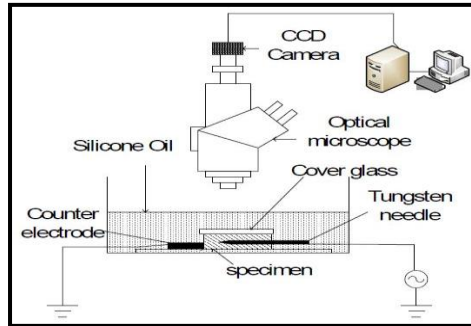


Figure 2. Experimental setup for electrical tree monitoring investigation and self-healing performance of SiR [7]

3. Results and Analysis

Figure 3 Shows the electrical tree propagation on neat SiR sample. The tree length of self-healing performance in this work was measured in time intervals 0, 144, 288, and 432 h, respectively. Figure 4 Shows the electrical tree length for neat SiR samples against elapsed time. As it can be seen from the figures, the tree length and the branches are reduced by increasing the elapsed time. The longer of elapsed time, the shorter the tree and branches length of the samples.

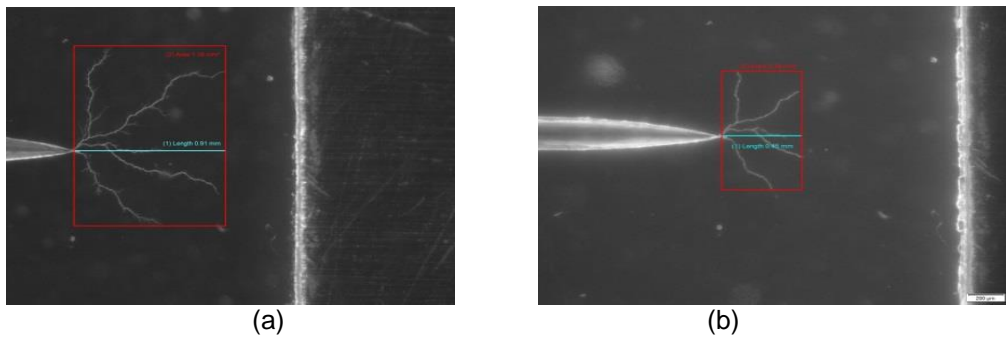


Figure 3. Self-healing performance of neat SiR for sample 1 at different of elapsed time, (a) 0h, (b) 432h

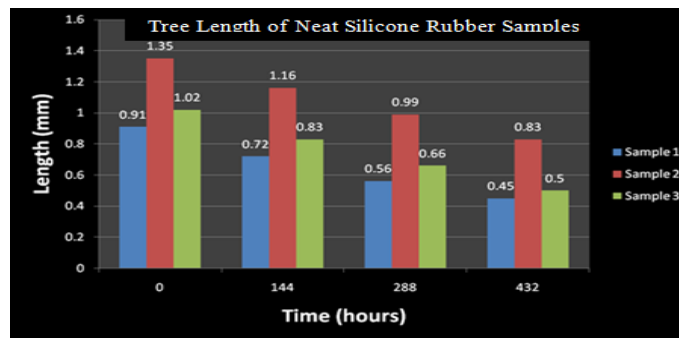


Figure 4. Tree length of self-healing performance for neat SiR sample against elapsed time

Figure 5 Shows the electrical tree propagation on neat SiR sample with 90% of humidity. While for electrical tree length for neat SiR with 90% of humidity samples against elapsed time is shown in Figure 6. The tree length reduction is smaller compared to the neat SiR.

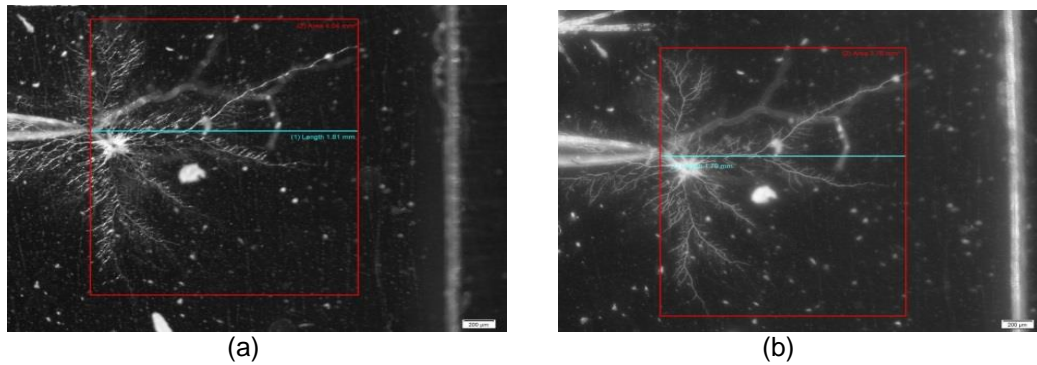


Figure 5. Self-healing performance of neat SiR with 90% of humidity for sample 1, (a) 0h, (b) 432h

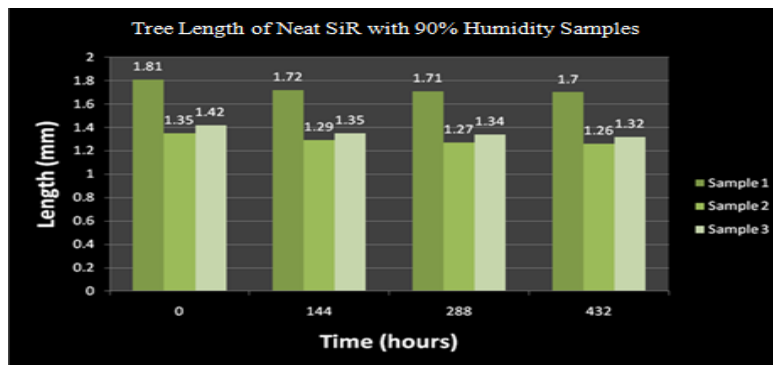


Figure 6. Three length of self-healing performance for neat SiR with 90% of humidity samples against elapsed time

Figure 7 Shows the electrical tree propagation on SiR sample added with 2wt% of SiO₂ nanofiller. Figure 8 Shows the electrical tree length for all samples against elapsed time. It was observed that the self-healing properties of the sample are smaller compared to the neat SiR samples.

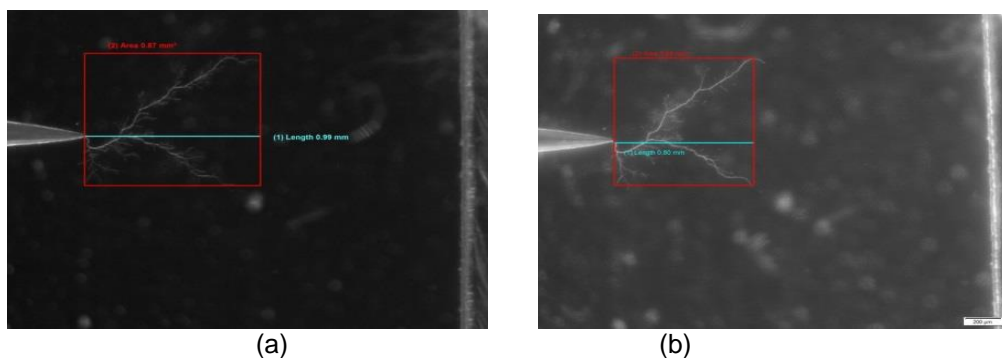


Figure 7. Self-healing performance of neat SiR added with 2wt% of SiO₂ nanofiller for sample 1 at different elapsed time, (a) 0h, (b) 432h

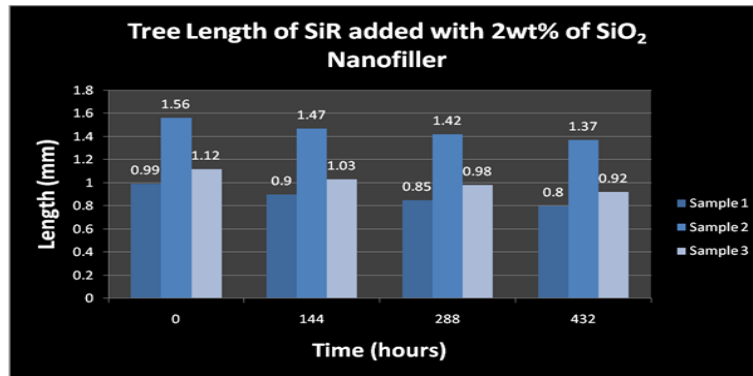


Figure 8. Tree length of self-healing for neat SiR added with 2wt% of SiO₂ nanofiller samples against different elapsed time

Figure 9 Shows the total tree length of all samples types. It is found that the longest length reduction is on neat SiR samples whereas the smallest reduction was occurred in the SiR sample added with 6wt% of SiO₂ nanofiller.

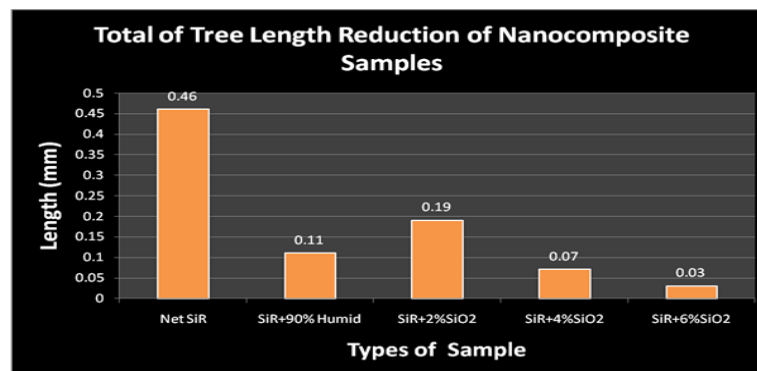


Figure 9. Total of tree length reduction for all samples

This phenomenon could be explained as follows. Neat silicone is a softer material than silicone rubber added with nanofillers. The existence of SiO₂ nanofiller in the SiR sample will increase the barrier in the material. Thus it will make the sample become harder. When nanofillers are well dispersed in a polymer matrix, it would result in delaminated or exfoliated particle structures. With this structure, electrical trees will follow the paths through the polymer or interface zones. A uniform arrangement of nanofillers causes electrical tree growth to be slowed down and therefore hindered [9].

In neat SiR samples, the tree patterns have number of branches with very small diameter and almost invisible. But in the case of the neat SiR with 90% humidity and silicone nanocomposites, the tree pattern is similar to the neat SiR samples but have larger diameter for the tree branches. The presence of the nanofiller, as the electrical tree propagate through the insulation, the electrons which are generated from high stress area collide with the nanoparticles, this in turn restrain the electron avalanches so that the tree channel takes a longer time to propagate in to the insulation compared to the neat SiR ones. With higher percentage of nanofiller, the number of obstructions will increase and tree channel will take more time to reach the opposite electrode (ground).

The treeing diameter obtained from neat SiR with 90% humidity samples are higher compared to the neat ones with room temperature. For 90% humidity, the propagation of the long tree branch almost reached to the ground electrode due to the present of the water layer and the insulation is wet and contaminated condition that would cause the insulation

breakdown. In deteriorated insulation may cause the leakage current in the cable insulation. Because of this, the insulation reduces its self-healing properties and may eventually damage.

4. Conclusion

Effect of humidity and nanofiller amount on self-healing performance of silicone rubber samples has been successfully investigated in this research work. Several important findings are as follows. The self-healing performance is better in neat silicone rubber samples compared to the ones with 90% of humidity. The presence of water layer in humid samples of insulation represents a wet and contaminated condition. Thus, their self-healing property is reduced and may eventually damage the samples. It was also found that the neat silicone rubber sample has better self-healing performance compared to the samples added with SiO₂ nanofiller. This is due to the different compositions of material in which neat silicone rubber is a soft material and thus electrical tree easily to propagates, leading to visible crack or damage on the samples. Self-healing performances of silicone rubber filled with lower percentage of nanofillers is better than those samples with higher percentage of nanofillers. Higher weight percentage (wt%) of nanofiller give slower recovery result.

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